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Paint Products Fact Sheet

To assess the risks for the consumer

Updated version for ConsExpo 4

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Abstract

Paint Products Fact Sheet

To assess the risks for the consumer

Updated version for ConsExpo 4

Exposure to compounds in consumer products is assessed using the computer program ConsExpo (Consumer Exposure). Given the huge number of consumer products, it is not possible to calculate the exposure for each separate product, so a limited number of groups containing similar products are defined. The information for each group of products is described in a fact sheet. Pest control products, cosmetics and cleaning products are examples of fact sheets, which have been published already.

This fact sheet covers the use of paint products by consumers. In the fact sheet, seven product categories are described, including brushing / rolling of several types of paint products and spraying paints with an aerosol spray can and pneumatic using a compressor. To assess exposure to compounds in paint products, default values for all seven product categories have been determined.

Keywords: paint, exposure, consumer, risk, compounds

Rapport in het kort

Factsheet verfproducten

Ten behoeve van de schatting van de risico's voor de consument
Geüpdate versie voor ConsExpo 4

Voor de conversie van het computerprogramma ConsExpo 3 naar 4 is de factsheet verf aangepast en herzien en nu ook in het Engels beschikbaar.

ConsExpo 4 is een computerprogramma, dat gebruikt kan worden om de blootstelling van mensen aan stoffen in consumentenproducten uit te rekenen. Hierbij wordt rekening gehouden met verschillende blootstellingroutes (dus via de huid, via inhalatie en via orale opname).

Bij het ConsExpo programma hoort ook een database, waarin standaardwaarden voor vele producttypen en voor een groot aantal blootstellingsscenario's worden aangeboden. De beschrijving van deze achtergrondinformatie bij deze standaardwaarden wordt gerapporteerd in zogenoemde 'factsheets'.

In dit rapport, factsheet verfproducten, is de meest recente informatie bijeengebracht om de blootstelling aan stoffen uit verfproducten te berekenen. De verschillende typen verfproducten zijn verdeeld in zeven categorieën, zoals het kwasten / rollen van verschillende soorten verf en het verspuiten van verf met een spuitbus en pneumatisch, met behulp van een compressor. Voor iedere categorie wordt de samenstelling en het gebruik van producten uit die categorie beschreven. Daarnaast wordt aangegeven welk model of modellen van ConsExpo het meest geschikt zijn om de blootstelling uit te rekenen en worden voor alle gegevens die nodig zijn voor de berekening, standaardwaarden ingevuld. Naast deze factsheet verfproducten zijn er ook factsheets voor ongediertebestrijdingsmiddelen, cosmetica, reinigingsmiddelen, doe-het-zelfproducten en desinfectantia.

Trefwoorden: verf, blootstelling, consument, risico, stoffen

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Summary

Proper information on exposure assessment is often lacking in current risk assessment. Mathematical models, such as ConsExpo, can be used when experimental data are limited to assess the exposure to consumer products and uptake of substances present. However, the large number of available consumer products prohibits the formulation of separate exposure models for every product. For this reason products are categorized into several main categories, such as disinfectant products, children's toys, cosmetics, pest control products, and cleaning products for which fact sheets have already been prepared at the National Institute for Public Health and the Environment (RIVM).

In the fact sheet presented here, information on the use of paint products is provided. The use of the commercially available products from the main category of paint products by consumers is described in seven product categories including brushing / rolling of several types of paint and spraying paints with an aerosol spray can and pneumatic, using a compressor. It aims to cover all uses of paint products with a restricted number of product categories. To achieve this goal, products are categorized by type of paint product use and consequently by type of exposure for consumers. Each product category deals with the composition and the use of the products within that specific category. To assess the exposure of substances from the use of paint products, default models under ConsExpo and default parameter values were determined.

Samenvatting

Om de blootstelling aan stoffen uit consumentenproducten en de opname daarvan door de mens te kunnen schatten en beoordelen zijn wiskundige modellen beschikbaar. Voor de berekening wordt gebruikgemaakt van het computerprogramma ConsExpo. Het grote aantal consumentenproducten maakt het onmogelijk voor elk afzonderlijk product blootstellingsmodellen en parameterwaarden te ontwikkelen. Daarom is een beperkt aantal hoofdcategorieën met gelijksoortige producten gedefinieerd. Voor elke hoofdcategorie wordt de informatie in een factsheet weergegeven. Cosmetica, ongediertebestrijdingsmiddelen, reinigingsmiddelen en desinfectantia zijn voorbeelden van factsheets die al gereed zijn. In deze factsheet wordt informatie gegeven over het gebruik van verfproducten. Het gebruik van verfproducten door consumenten wordt beschreven met behulp van zeven productcategorieën, zoals het kwasten / rollen van verschillende soorten verf en het verspuiten van verf met een spuitbus en pneumatisch, met behulp van een compressor. Het gehele gebied van het gebruik van verfproducten door consumenten wordt met deze productcategorieën bestreken. Voor elke productcategorie is de samenstelling en het type gebruik van producten gespecificeerd. Om de blootstelling van stoffen uit verfproducten te kunnen schatten en beoordelen zijn voor elke productcategorie standaardmodellen ontwikkeld en standaardwaarden voor de parameters vastgesteld.

1 Introduction

1.1 General

Descriptive models have been developed within the RIVM to be able to estimate and assess the exposure to chemical compounds in consumer products and the uptake of these compounds by humans. These models are brought together in a computer program called ConsExpo 4. When a model is chosen in ConsExpo, and the required parameters are filled in, the program calculates the exposure to, and the uptake of, the compound involved.

Because of the large number of consumer products currently on the market, it is not possible to determine exposure models and parameter values for each individual product. Therefore, a limited number of main categories of similar products have been defined. Examples of the main categories are paint products, cleaning products, cosmetics and pest control products. The relevant information with respect to estimating exposure to and the uptake of compounds from consumer products is given in a fact sheet for each of the main categories. These fact sheets can be used to characterize and standardize the exposure.

This fact sheet supplies information on the main category paint products. Paint products cover paints, varnishes and lacquers.

Within a main category as few categories as possible are defined, which together describe the entire main category. The paint products main category includes the following product categories: brush and roller painting of several types of paint, spray painting with a spray can and pneumatic, using a compressor. The composition and the use of the type of products within the category are examined for every product category. To estimate the exposure and uptake of compounds from paint products, default models with default parameter values are determined for every product category in this fact sheet. The default models and default parameter values are available via a database. Using these data, standardized exposure calculations for consumers resulting from the use of paint products can be performed.

1.2 ConsExpo

ConsExpo is a software tool for Consumer Exposure assessment. ConsExpo is a set of coherent, general models that can be used to calculate the exposure to compounds from consumer products and their uptake by humans. It is used for the consumer exposure assessment for new and existing substances within the framework of Directive 67/548/EC and the Council Regulation 793/93/EC, respectively. Furthermore, ConsExpo is also one of the models that is used to assess the consumer exposure to biocides (Technical notes for guidance (TNsG): Human exposure to biocidal products – Guidance on exposure estimation¹⁾ (<http://ecb.jrc.it>)).

ConsExpo was built using data on the use of products, and using mathematical concentration models. The program is based on relatively simple exposure and uptake models. The starting point for these models is the route of exposure that means the inhalatory, dermal or oral route. The most appropriate exposure scenario and uptake model is chosen for each route. The

parameters needed for the exposure scenario and the uptake models are then filled in. It is possible that exposure and uptake occur simultaneously by different routes. In addition to data about the exposure and uptake, contact data are also needed, such as the frequency of use and the duration of use. Using the data mentioned above, ConsExpo calculates the exposure and uptake.

ConsExpo 4, the most recent ConsExpo version, is described in detail in Delmaar et al.²⁾

ConsExpo 4 can be used for a screening assessment or for an advanced (higher tier) assessment. For every exposure route i.e. inhalation, dermal and oral route, different models are offered for calculating external exposure. ConsExpo also integrates the exposure via the different routes resulting in a systemic dose. Different dose measures can be calculated (acute, daily, chronic exposure). ConsExpo can also run calculations using distributed input parameters and sensitivity analyses can be performed.

The computer model is publicly available. Default data are available via the database, which is an integral part of ConsExpo. The software, the user manual and the various fact sheets (see section 1.3) can be downloaded via the website of the National Institute for Public Health and the Environment in the Netherlands (RIVM; www.rivm.nl/consexpo)

1.3 Fact sheets

This report is one of a series of fact sheets that describes a main category of consumer products, such as cosmetics, pest control products, do-it-yourself products and, in this report, paint products. The fact sheets give information that is important for the consistent estimation and assessment of the exposure to, and the uptake of, compounds from consumer products.

A separate fact sheet called the ‘General Fact Sheet’³⁾ gives general information about the fact sheets, and deals with subjects that are important for several main categories. The General Fact Sheet gives details of:

- the boundary conditions under which the defaults are estimated;
- the way in which the reliability of the data is shown;
- parameters such as the ventilation rate and room size;
- parameters such as body weight, the surface area of the human body and parts of the body.

In the facts sheets, information about exposure to chemical compounds is collected into certain product categories. These categories are chosen so that products with similar exposures are grouped. On the one hand, the fact sheets give general background information; while on the other hand, they quantify exposure parameters which, together with one or more of the ConsExpo exposure models, produce a quantitative estimate of the exposure.

The fact sheets are dynamic documents. As new research becomes available or as perceptions change, the parameter default values may need to be changed. Additional models can also be developed within ConsExpo; this too will require adaptations. The fact sheets are linked with ConsExpo since the fact sheets define the default values for the parameters used in the different ConsExpo models. Alterations in either the parameter default values or the models influence both the fact sheets and (data base of) ConsExpo. We intend to produce updates of the published fact sheets on a regular basis.

This fact sheet is principally aimed at exposure to the whole product and is, as such, independent of the compound. This means that the information about the compound must be added separately. This mainly concerns information about the concentration and the physico-chemical properties of the compound.

1.3.1 The consumer and exposure

Non-professional use only

The default values in the fact sheets have been collected for consumers (private or non-professional users). They are not aimed at describing exposure for people who professionally work with paint products, such as painters. This fact sheet, therefore, only describes paint products, which are available to the consumer for private use.

Using the models in ConsExpo and the default values for consumers presented here as background data, it is nonetheless possible to calculate the exposure and uptake of paint products by professional users. Of course, the differences in products and product use between the consumer and those using paint products professionally must be taken into account.

1.3.2 'Reasonable worst case' estimate

The basis for the calculation and/or estimation of the default parameter values is a realistic worst-case scenario, and considers consumers who frequently use a certain paint product under relatively less favourable circumstances. For example, when using a paint product, basic assumptions include relatively frequent use, application of a relatively large amount in a small room with poor ventilation and a relatively long stay in that room.

The parameter values in the fact sheets are aimed at (Dutch) consumers. They are chosen such that a relatively high exposure and uptake are calculated, in the order of magnitude of a 99th percentile of the distribution. To achieve this goal, the 75th or the 25th percentile is calculated (or estimated) for each parameter. The 75th percentile is used for parameters, which give a higher exposure for higher values, and the 25th percentile is used in the reverse case. For a significant number of parameters, there are actually too little data to calculate the 75th or 25th percentile. In such cases, an estimate is made which corresponds to the 75th or 25th percentile.

Multiplication of two 75th percentile parameter values will result in a 93.75th percentile, whereas multiplication of three 75th percentile parameter values will result in a 98.5th percentile. Since a 75th /25th percentile is calculated or estimated for all parameter values, the resulting outcome in the calculation is a higher exposure and/or uptake. Given the number of parameters and the relationship between the parameters, it is expected that in general the calculated values for exposure and uptake will result in a 99th percentile.

The result is a 'reasonable worst case' estimate for consumers who use relatively large amounts of paint products under less favourable circumstances.

Usually the use of gloves is not advised during painting. If in the directions for use wearing gloves is advised it can be assumed that a substantial part of the users will not follow the instructions. In the exposure assessments will, worst case, be assumed that application without gloves will occur.

1.3.3 Reliability of the data

A number of parameters is difficult to estimate based on literature sources and unpublished research. A value must still be chosen for these parameters; otherwise it is not possible to carry out any quantitative exposure assessments. This is why a quality factor (Q-factor) has been assigned to all parameter values in the fact sheets, indicating the reliability of the estimate of the default value (see Table 1). Low quality factors of 1 or 2 indicate that the default value is based on insufficient (or no) data. If such a default is used in an exposure analysis, it should be carefully considered and, if possible, adapted. If representative data are supplied by applicants or producers, it can replace the default values. High quality factors of 3 or 4 indicate that the defaults are based on sufficient (or more than sufficient) data. These defaults generally require less attention, although, they may need to be adapted to specific exposure scenarios. For example, an exposure estimate might be carried out for a room of a particular size. The well-established default room size should then be replaced by the actual value.

Compared to the previous fact sheets the quality factor range has been adapted and ranges now from 1 to 4. In previous fact sheets, the quality factor ranged from 1 to 9.

Table 1: Value of quality factor Q

Q	Value
4	Good quality relevant data, parameter value reliable
3	Number and quality of the data satisfactory, Parameter value usable as default value
2	Parameter value based on single data source supplemented with personal judgement
1	Educated guess, no relevant data available, parameter value only based on personal judgement

1.4 Classification into product categories

For this fact sheet, paint products are classified into product categories, which are drawn up according to the type product and the application method. The aim is to reduce the large number of individual products and applications to a limited number of product categories. The method of exposure within each product category is very similar, so that one default exposure estimate can be drawn up for all products, which belong to that category.

From, for instance, the study of Weegels⁴⁾ can be derived that there is a relationship between type of paint, use duration and product amount. Spray cans with paint are usually applied during a short time. Latex wall paint is usually applied for large surfaces in larger quantities and the application duration will be relatively long. The quantity of paint used per unit of time when painting a chair or a window frame will be much smaller than when painting a lathed wall or varnish a floor.

If paint is sprayed, aerosol particles are formed which can be inhaled, which may lead to inhalation exposure to non-volatile compounds present in the paint.

Therefore the exposure to compounds in paint products will depend not only on the circumstances during painting but also of the type of paint and the application method.

In the fact sheets, realistic worst case scenarios are chosen to describe the exposure (see section 1.3.2). Therefore circumstances are chosen in such a way that it will lead to relatively high exposure, painting a relatively large surface in a small room, with low ventilation. That means that for example the painting of a wall is chosen as default scenario and not the painting of a chair or a window frame.

Classifying paint products in product categories the types of paints and the application methods should be considered first.

1.4.1 Types of paint

There are a lot of different paint products, for many different applications. Nevertheless almost all paint products consist of the components described below:

- binders
- solvents (including water)
- pigments and fillers
- additives.

After drying, the *binder* builds up the actual paint layer. The binder ‘binds’ the other compounds, like pigments and fillers, together. Usually the binder is a synthetic material. The binder defines for a main part the technical properties of the paint. Therefore a kind of paint is usually called after its binder: alkyd paint, acrylate paint, chlorinated rubber paint, epoxy and polyurethane paints, etc.

The *solvent* in paint provides the dissolving of the binder or other components in the paint, provides the diluting of the paint, a good processability, a quick drying, improvement of the flow (Dutch: vloeï) of the paint and improvement of the penetration in the substrate.

Waterborne paints contain solvents too, their function is to slow down the drying process of the paint and to achieve a good formation of the paint film on the surface.

In solvent rich paints and high solids usually mixtures of solvents, like turpentine, thinner and white spirit, are applied. Glycols and glycol-ethers are often used solvents in waterborne paints.

Pigments provide the covering power and colour of paints. Some pigments are anti-corrosive too, or protect against UV-light (sunlight). There are pigments with a base of metals, like iron. Furthermore there are ‘organic’ pigments with a base of organo-chemical compounds. 90 % of the consumption of pigments consists of the white pigment titanium dioxide.

Fillers provide ‘body’ and layer thickness. Lime (calcium-carbonate) is used the most by far as a filler, other types of fillers are quartz and clayey compounds.

Additives are added to paints to improve the technical properties of the paint. Usually the total content of additives is low, less than 5 %. The percentage of the individual additives usually is lower than 1 %. There are dozens of additives: anti-foam, preservatives, dryers, flow improvers, wetting agents and pH-controllers.

In this fact sheet, paint products are classified in five types of paint (see Table 2).

Differences in the exposure pattern of the paint products are starting point for this classification. Other points of importance are:

- The paint layer formed with high solids usually is thicker than with solvent rich paints.
- Waterborne paints contain quite different types of solvents than solvent based paint products.
- Waterborne paints usually dry faster than solvent based paints.
- The use of waterborne paints by consumers will be quite different in comparison with paints based on organic solvents, especially when hands are cleaned during painting and the cleaning of brushes after the painting. These differences can affect the dermal exposure.
- Two component paints consist of, binders, solvents, pigments and fillers and additives, just like other paints. Furthermore, one of the two components will contain a hardener. Immediately before use the two components have to be mixed. Because two component paints have to be mixed before use, which can cause dermal exposure, they are classified separately. Furthermore the mechanism of drying is quite different from other paints.

Tabel 2: Classification of types of paint products used by consumers (composition mainly derived from: <http://www.veilgmetverf.nl/pages/template.php?rID=227>, dd 13-3-2006)

Types of paint	Binder	Solvent	Pigment / filler
solvent rich paints	ca 35 % mostly alkyd	40-50 % organic solvents	20-30 % pigment hardly no filler
high solids	ca 45 % mostly alkyd	20-30 % organic solvents	20-30 % pigment hardly no filler
waterborne paints dispersions	30 % acrylate, polyurethane (PUR), acrylate-PUR	40 % water 5-10 % organic solvents	20-30 % pigment hardly no filler
emulsions	30 % alkyd	35 % water 2-3 % organic solvents	20-30 % pigment hardly no filler
waterborne wall paints	5-10 % mostly acrylate	mainly water 1-2 % organic solvents	less pigment much filler
2 component paints	epoxy, polyurethane	solvent rich high solid water borne	20-30 %

The classification as described above can be used for all types of paints applied by consumers. Some types of paints are little applied by consumers, for specific applications, such as chlorinated rubber paints and coatings for plastics. For example chlorinated rubber paints can be used for painting boats. For these special types of paint no separate product categories are formulated, the types of paints as described in Table 2 can be used too for these paints.

Information about the composition and use of these special paint products is described in a separate sub-section (§ 2.8; miscellaneous, special paint products).

1.4.2 Application methods

Paint products can be applied with a brush or a roller, furthermore paints can be sprayed. Considering the human exposure to compounds from paint products the difference between brushing and use of a roller will be negligible. Therefore no separate product categories are described for brushing and rolling.

Consumers can spray paint with aerosol spray cans and to a lesser degree also using a compressor. When using a compressor paint products are sprayed almost always pneumatic. Both spraying with aerosol spray cans and pneumatic spraying will be described.

1.4.3 Product categories

For combinations of types of paint products and application methods seven product categories are defined, based on the principle that a similar exposure takes place within a category (see Table 3). The product categories are proposed as such that they should cover the entire field of paint products use by consumers.

Table 3: Product categories paint products

Brush and roller painting
solvent rich paint
high solid paint
waterborne paint
wall paint, waterborne
two component paint
Spray painting
spray can
pneumatic

In chapter 2, default ConsExpo models for the exposure of brush and roller painting are described and default parameter values are derived. Chapter 3 describes the spraying of paint products by consumers.

The ConsExpo models themselves are not discussed in this report, they are discussed in detail in Delmaar et al.²⁾

If an exposure route for a certain category is considered negligible, no default models are described for that route. For example, when brushing a paint, only the inhalation and the dermal exposure route are of importance, the oral route will usually be negligible.

1.5 Uncertainties and limitations

This fact sheet presents a number of default parameters, which can be used in the exposure assessment of the non-professional user of paint products, when using ConsExpo. The model approach makes it possible to extrapolate data for certain products to other products and other scenarios, for which there are no specific data. The determination of default values for the various model parameters also ensures that a high degree of consistency can be achieved in the assessments.

One should realize that the exposure estimates from a model depend on the quality and the reliability of the input-data. It is therefore recommended that one is alert in the choice of parameter values and the adaptation of default values. Scenarios and the related parameters can have a major influence on the final exposure estimate. It should also be noted that the

models used in ConsExpo are developed for particular purposes. In the absence of specific models, one is forced to use a model developed for another purpose.

Future versions of ConsExpo and updates of fact sheets will elaborate on these aspects once more data are available. Depending on what is needed, examples of improvements may include further adaptation of exposure models for certain scenarios or development of new models.

2 Brush and roller painting

In this chapter brush and roller painting is described for five different types of paint, solvent rich, high solid and waterborne paint, waterborne wall paint and two component paint. For each type of paint a scenario is formulated, the most relevant models are chosen, and filled up with parameter values. In the sections 2.1 and 2.2 parameter values are discussed, which are of importance for several scenarios.

2.1 Default values inhalation exposure

In this section, parameter values are discussed of the evaporation model, which describes the inhalation exposure to vapours.

2.1.1 Application duration/ exposure duration

In the evaporation model, the application duration (the time someone is painting) is one of the parameter values, just like the exposure duration (the time someone is exposed to the vapours). Usually the room in which painting has been taken place, will be left after painting. It is assumed that after painting the room is cleaned up and that the room is left afterwards. The exposure duration is set at 1.1 times the application duration, to account for the clean-up time.

2.1.2 Mass transfer rate

The mass transfer rate is determined by the rate at which the compound is transported away from the evaporation surface. In general this transport will depend on the rate of diffusion of the compound through air, and the rate of air movement above the product-air surface.

Langmuir's method effectively assumes that diffusion of the compound is infinitely fast. It will as a rule highly overestimate the evaporation rate and predict higher peak concentrations than the Thibodeaux approximation. Thibodeaux' method is a simple approximation of the more elaborate Liss-Slater two-layer model, describing the evaporation of a compound from water.

Mass transfer rates calculated using the Thibodeaux' method will be lower than the ones calculated by Langmuir's method, but it should be remembered that this method is only an approximation of a specific system (evaporation of a solute from water) and has limited validity outside the domain for which it was derived.

Therefore the Langmuir's method is set as default method, except in waterborne systems, then Thibodeaux' method is chosen.

2.1.3 Molecular weight of the matrix

The molecular weight of the matrix (or: mol weight matrix) is the weighted average of the matrix, which contains the chemical of interest.

If the product is a mixture of compounds in the evaporation model the parameter 'mol weight matrix' has to be specified. In a mixture of compounds the evaporation of a specific

compound depends on the partial equilibrium vapour pressure of the compound in the mixture P_{eq} . The latter is approximated by Raoult's law:

$$P_{eq} = \left(\frac{P_{vap} C_v}{C_v + C_r \frac{M}{M_r}} \right),$$

where:

P_{vap}	:	saturated vapour pressure of the compound as a pure substance	[Pa]
M	:	molecular weight of the compound	[kg/mole]
C_v	:	concentration of the compound in the product	[kg/m ³]
C_r	:	concentration of the rest of the material in the product	[kg/m ³]
M_r	:	mol weight matrix, average molecular weight of the rest of the material	[kg/mole]

The mol weight matrix M_r is determined from the molecular weights and concentrations of the product ingredients as:

$$\frac{C_r}{M_r} = \frac{(1 - w_f) \times \rho}{M_r} = \sum_i \frac{C_i}{M_i} = \sum_i \frac{w_i \times \rho}{M_i}$$

and thus:

$$M_r = \frac{1 - w_f}{\sum_i \frac{w_i}{M_i}}$$

where the index i refers to the ingredients of the rest of the material and ρ is the mass density of the total product (including the compound of interest) and w_f is the weight fraction of the compound in the product [unit: fraction].

Raoult's law is valid only for ideal, non-interacting liquids and constitutes only an approximate description of a real situation.

If the composition of a paint product is known, the 'mol weight matrix' can be calculated with the formula above.

Mostly the mol weight and the concentration of all components of a paint product are unknown. For this situation, default values are derived.

For the calculation of the mol weight of the matrix two situations have to be distinguished:

- the main solvent in the paint is the compound of interest;
- the main solvent is not the component of interest.

In the formula for the mol weight matrix (see above) only compounds with relatively low mol weights, which occur in relative high concentrations in a paint product, make a valuable

contribution to the $\sum_i \frac{w_i}{M_i}$. If the mol weight of components in paint products is very high,

like binders, the contribution to $\sum_i \frac{w_i}{M_i}$ can be neglected, compared to solvents, which occur mostly in about the same quantities.

The mol weight of binders in a solvent rich paint is ca 3,000 -5,000 g/mol; in waterborne paints about 500.000 ^{a), b)}. The mol weight of solvents in solvent rich paint is in the order of magnitude of 140 g/mol. In waterborne paint, water (mol weight: 18 g/mol) is of course the main solvent.

The main solvent in the paint is not the component of interest

The concentration of the compound of interest (w_f), which is not the main solvent, will be almost always smaller than 10 %. For the calculation of the default value of the mol weight matrix w_f can be neglected with respect to 1; or $1-w_f \approx 1$.

$$\text{Mol weight matrix} \approx \frac{1}{\sum_i \frac{w_i}{M_i}}$$

In paint products, compounds with mol weights substantially lower than the main solvent will usually not occur. The value of $\sum_i \frac{w_i}{M_i}$ depends mostly on the main solvent.

For the calculation of the default value of the mol weight matrix the contribution of the other solvents may usually be neglected. This means that mol weight matrix $\approx \frac{M_{\text{main_solvent}}}{w_{\text{main_solvent}}}$

Based on these assumptions default values for the mol weight matrix are calculated for the different types of paint products, the default values are described in Table 4.

The main solvent in the paint is the compound of interest

If the main solvent in the paint is the compound of interest, $\sum_i \frac{w_i}{M_i}$ of the other compounds in

the paint usually will be very small, because the concentration w_i of other solvents, if available, will be relatively small with respect to the main solvent. Components, which can occur in quantities comparable with the contribution of the main solvent in the paint (such as binders), mostly have (very) large mol weights.

In this case, it is assumed that the vapour pressure of the main solvent is not influenced by the other compounds in the paint. In the formula this assumption is expressed in a value for the mol weight matrix of 3000 g/mol (see Table 4).

a) Personal communications VVVF, dd 24-10-1997; 12-11-1998

b) Personal communications TNO-Industrie, dd 22-12-1997; 12-11-1998

Tabel 4: Default values mol weight matrix, when the compound of interest is the main solvent and when the compound of interest is not the main solven.

Type of paint	Composition	Mol weight matrix [g/mol]	
		The compound of interest is the main solvent	The compound of interest is not the main solvent
solvent rich paint	45 % solvent, Mw 140	3000	300
high solid paint	25 % solvent, Mw 140	3000	550
waterborne paint	40 % water, Mw 18	--	45
wall paint, waterborne	15 % water, Mw 18	--	120

2.1.4 Boundary conditions evaporation model

To calculate the inhalation exposure of compounds from paint products, models which describe the evaporation of compounds from a mixture of liquids will be used. The evaporation from drying paint products can be estimated with these models. These models are not suitable to estimate the emission of compounds from hardened paint products

2.2 Default values for dermal exposure

To describe the dermal exposure during brushing or rolling paint products the ‘constant rate model’ from ConsExpo is used.

For this model the parameter ‘contact rate’ is required. The contact rate is the rate at which the product is applied to the skin, in weight per time unit. The ‘constant rate model’, is described in detail in Delmaar et al.²⁾

In the Technical Notes for Guidance¹⁾ dermal exposure values are described of experiments with brushing and rolling of wood preservatives and antifouling by consumers (see Table 5).

In the TNsG brushing and rolling of wood preservatives and antifouling is described, not the brushing and rolling of paint products. The dermal exposure during brushing / rolling of paint products will depend on the viscosity of the paint. If a type of paint is more viscous (i.e. thicker) it is assumed that the dermal exposure will be smaller. Usually the viscosity of wood preservatives will be lower than paint products.

It is assumed that the viscosity of wood preservatives will be in the same order of magnitude as a low viscous paint product like varnish, and that the viscosity of antifouling is comparable to paint products.

Dermal exposure during brushing / rolling will depend on the position of the user, as can be demonstrated for wood preservatives from Table 5. This will apply to paint products too.

If someone is painting overhead (the ceiling) the dermal exposure will be substantially higher than when painting downwards (the floor) or painting directed to the side (a wall).

Therefore for the default values a distinction is made between painting overhead and ‘other directions’ (downward painting and painting directed to the side). Only for painting overhead a distinction is made between low viscous paint products and ‘other paints’, for downward painting and painting directed to the side, this could not be done due to a lack of information. Therefore it is assumed that dermal exposure during downward painting and painting to the side is the same for both low viscous paint products and other paints (see Table 6).

Table 5: Dermal exposure during brushing and rolling of wood preservatives and antifouling

Task	Product	Dermal exposure			
		50 th % value		75 th % value	
		mg/min	% on hands	mg/min	% on hands
brush painting of rough wooden joists and the undersides of floorboards, overhead indoors (includes decanting)	water-based wood preservative	128.8	85	185.7	81
brush painting sheds and fences	water-based wood preservative	8.15	31	20.12	31
	solvent-based wood preservative	30.78	20	49.7	39
brush painting sheds and fences	wood preservative	8.55	41	22.86	26
brush and roller painting antifoulant on the underside of small boats (leisure craft) The product was mixed and applied by brush direct from the can, or poured to a paint tray and applied by roller. The task was mostly done outdoors in a cramped position, with the single-hull boat (one double-hull) on a sling, cradle or trailer	antifouling	89.0	82	> 124.1	

During painting overhead predominantly the hands will be dermally exposed. For wood preservatives and antifouling more than 80 % of the total dermal exposure is onto hands (see Table 5). When painting to the side this percentage ranges from 20 to 40 %.

To get an idea of the quantity of paint, which ends up on the hands during painting, a few simple experiments were executed. One hand was stained with poster paint.

It was attempted to stain the hand slightly, moderately and seriously. ‘Slightly stained’ means only some small paint spots. The hand stained in a high amount, which usually will not occur, is defined as ‘seriously stained’. The quantity of paint to stain the hand was measured. The measurements were executed twice with blue and with white paint. The quantity of paint on a slightly stained hand was circa 50 mg, on the moderately stained hand circa 150 mg, and on the seriously stained hand circa 800 mg.

If during painting the quantity of paint on the hands will be larger, the hands will be cleaned or wiped off anyhow. It is assumed that when a hand is ‘seriously stained’ with paint (more than about 1 g of paint) the hand will be cleaned or wiped off. Cleaning of the hands is not taken into account in the exposure values for wood preservatives and antifouling as described in Table 5. As described before, it is assumed that consumers do not wear gloves during painting. For the default values of the dermal exposure during brushing and rolling of paint products, cleaning of the hands has to be taken into account in the default values.

Based on the data above, default values for dermal exposure during brushing and rolling of paint products are described in Table 6. The default values in Table 6 for the higher exposures levels are somewhat smaller than the corresponding (75th percentile) values in Table 5, due to cleaning of the hands. Otherwise, the exposure estimate would become unrealistic.

Table 6: Default values for the 'contact rate' during brushing and rolling of paint products

Position	Type of paint	Contact rate [mg / min]	Q
overhead painting	low viscosity (for example: varnish)	120	2
overhead painting	'normal' viscosity (for example: solvent rich paint)	60	2
downward painting and painting directed to the side	all paint products	30	2

2.3 Brush / roller painting, solvent rich paint

Composition

General composition of a conventional solvent rich paint⁶⁾

Binder	± 35 %	for example alkyd resin
Pigment	25 %	for example titanium dioxide
Solvent	40-50 %	for example white spirit
Additives	± 2 %	dryer 1 %; anti-skin product (Dutch: anti vel) 0.2-0.5 %; anti-sag product (Dutch: anti uitzak) 0.5 %; moistener 0.5 %

The density of a solvent rich paint is about 1.2 g/cm³ (product information, <http://www.sikkens.nl/nl/Products/ProductsOverview>, dd 6-10-2006).

Use

According to the directions for use the paint coverage is about 12-15 m²/l (product information, <http://www.sikkens.nl/nl/Products/ProductsOverview>, dd 6-10-2006).

Scenario

The scenario describes the brushing or rolling of a wooden lathed wall in a small room with low ventilation. Room size and ventilation rate as described in the General Fact Sheet³⁾ for an unspecified room (volume 20 m³, ventilation rate 0.6 h⁻¹).

Painted surface, release area

Room: 20 m³ (see scenario); l x w x h = 4 x 2 x 2.5 m

The surface of the wooden wall is 4 x 2.5 = 10 m²

Product amount

For painting a wooden wall of 10 m² 0,833 l or 1000 g paint is necessary (paint coverage 12 m²/l (see use), density 1.2 g/cm³ (see composition)).

Default values brush / roller painting, solvent rich paint

	Default value	Q	Reference, comments
General			
Frequency	1 year ⁻¹	3	usage 2 times a year one or a few days after each other, once per 2 years, estimation based on ^{4,7)}
Body weight	65 kg	4	adult ³⁾
Inhalation			
<i>Exposure to vapour: evaporation from increasing area</i>			
Exposure duration	132 min	2	see section 2.1.1
Application duration	120 min	2	estimate
Product amount	1000 g	3	see above
Room volume	20 m ³	3	unspecified room ³⁾
Ventilation rate	0.6 h ⁻¹	3	unspecified room ³⁾
Release area	10 m ²	3	see above
Temperature	20 °C	4	room temperature
Mass transfer rate	Langmuir		see section 2.1.2
Mol weight matrix	300 g/mol	3	see section 2.1.3
Dermal			
<i>Constant rate</i>			
Contact rate	30 mg/min	2	see section 2.2
Release duration	120 min	2	see above (release duration is application duration)

2.4 Brush / roller painting, high solid paint**Composition**

General composition of a high solid paint⁶⁾

Binder	± 45 %	for example alkyd resin
Pigment	25 %	for example titanium dioxide
Solvent	25-30 %	for example white spirit
Additives	± 2 %	dryer 1 %; anti-skin product 0.2-0.5 %; anti-sag product 0.5 %; moistener 0.5 %

The density of a high solid paint is about 1.3 g/cm³ (product information, <http://www.sikkens.nl/nl/Products/ProductsOverview>, dd 6-10-2006).

Use

According to the directions for use the coverage of paint is about 10-14 m²/l (product information, <http://www.sikkens.nl/nl/Products/ProductsOverview>, dd 6-10-2006).

High solid paints usually produce thicker paint layers than conventional solvent rich paints (product information: http://www.sikkens.nl/nl/Products/info_sheets/, dd 6-10-2006; personal communication VVVF, dd 22-03-2007).

Solvent rich paint	paint layer wet: 60 μm	paint layer dry: 30 μm
High solid paint	paint layer wet: 60 μm	paint layer dry: 39 μm .

Scenario

The scenario describes the brushing or rolling of a wooden lathed wall in a small room with low ventilation. Room size and ventilation rate as described in the General Fact Sheet ³⁾ for an unspecified room (volume 20 m³, ventilation rate 0.6 h⁻¹).

Painted surface, release area

Room: 20 m³ (see scenario); l x w x h = 4 x 2 x 2.5 m

The surface of the wooden wall is 4 x 2.5 = 10 m²

Product amount

For painting a wooden wall of 10 m², 1 liter or 1300 g paint is required (paint coverage 10 m²/l (see use), density 1.3 g/cm³ (see composition)).

Default values brush / roller painting, high solid paint

	Default value	Q	Reference, comments
<i>General</i>			
Frequency	1 year ⁻¹	3	usage 2 times a year one or a few days after each other, once per 2 years, estimation based on ^{4,7)}
Body weight	65 kg	4	adult ³⁾

Inhalation

Exposure to vapour: evaporation from increasing area

Exposure duration	132 min	2	see section 2.1.1
Application duration	120 min	2	estimate
Product amount	1300 g	3	see above
Room volume	20 m ³	3	unspecified room ³⁾
Ventilation rate	0.6 h ⁻¹	3	unspecified room ³⁾
Release area	10 m ²	3	see above
Temperature	20 °C	4	room temperature
Mass transfer rate	Langmuir		see section 2.1.2
Mol weight matrix	550 g/mol	3	see section 2.1.3

Dermal

Constant rate

Contact rate	30 mg/min	2	see section 2.2
Release duration	120 min	2	see above (release duration is application duration)

2.5 Brush / roller painting, waterborne paint

Composition

There are two types of waterborne paint products. Waterborne dispersion paints are the most widely used. The newer waterborne emulsion paints are used on a smaller scale.

In dispersion paints the synthetic binder (acrylate, polyurethane (PUR), or a mixture of both) is dispersed in water in small bulbs. In emulsion paints the binder is emulsified in water as small liquid bulbs. In both dispersion paints and emulsion paints the solvents evaporate slowly. For the main part, they will evaporate after water is evaporated. Frequently used solvents are texanol, glycol-ethers and propylene glycol^{8,9)}. In Table 7 the general composition of both types of paint is described.

Table 7: General composition of waterborne paints^{8,9)}

Component	Dispersion paint		Emulsion paint	
	Content [%]	for example	Content [%]	for example
Water	40		40	
Binder	28	20 % acrylate, 8 % PUR	30	alkyd resin
Pigment	20	20 % titanium-dioxide	25	titanium-dioxide
Solvents	8.5	6 % propylene glycol, 2 % di- propylene glycol monomethyl ether	2	propylene-glycol, butoxy-ethanol
Additives	3.5	0.5 % N-methyl pyrrolidin 1 % thickener; 0.3 % pH controller; 0.5 % disperser; 0.01 % preservative	3	1 % dryer; 0.3 % anti-skin product; 0.1 % anti-foam; 0.5 %; thickener; 0.01 % preservative

The density of waterborne paint is about 1.25 g/cm³ (product information, <http://www.sikkens.nl/nl/Products/ProductsOverview>, dd 6-10-2006).

Use

According to the directions for use the coverage of paint is about 10-14 m²/l (product information, <http://www.sikkens.nl/nl/Products/ProductsOverview>, dd 6-10-2006).

Scenario

The scenario describes the brushing or rolling of a wooden lathed wall in a small room with low ventilation. Room size and ventilation rate as described in the General Fact Sheet³⁾ for an unspecified room (volume 20 m³, ventilation rate 0.6 h⁻¹).

Painted surface, release area

Room: 20 m³ (see scenario); l x w x h = 4 x 2 x 2.5 m

The surface of the wooden wall is 4 x 2.5 = 10 m²

Product amount

For painting a wooden wall of 10 m², 1 liter or 1250 g paint is necessary (paint coverage 10 m²/l (see use), density 1.25 mg/cm³ (see composition).

Default values brush / roller painting, waterborne paint

	Default value	Q	Reference, comments
General			
Frequency	1 year ⁻¹	3	usage 2 times a year one or a few days after each other, once per 2 years, estimation based on ^{4,7)}
Body weight	65 kg	4	adult ³⁾
Inhalation			
<i>Exposure to vapour: evaporation from increasing area</i>			
Exposure duration	132 min	2	see section 2.1.1
Application duration	120 min	2	estimate
Product amount	1250 g	3	see above
Room volume	20 m ³	3	unspecified room ³⁾
Ventilation rate	0.6 h ⁻¹	3	unspecified room ³⁾
Release area	10 m ²	3	see above
Temperature	20 °C	4	room temperature
Mass transfer rate	Thibodeaux		see section 2.1.2
Mol weight matrix	45 g/mol	3	see section 2.1.3
Dermal			
<i>Constant rate</i>			
Contact rate	30 mg/min	2	see section 2.2
Release duration	120 min	2	see above (release duration is application duration)

2.6 Brush /roller painting, waterborne wall paint**Composition**

General composition of waterborne wall paint¹⁰⁾

Water	15 %	
Binder	5 %	for example styrene-acrylate resin
Pigment	8%	for example titanium dioxide, iron oxides
Filler	70 %	for example lime, clayey minerals
Solvent	1-2 %	for example methoxy-propanol, white spirit
Additives	2-3 %	for example 0.2 % anti-foam; 0.5 % disperser; 0.02 % pH controller; 0.01 % preservative

The density of waterborne wall paint is about 1.5 g/cm³ (product information, <http://www.sikkens.nl/nl/Products/ProductsOverview>, dd 6-10-2006).

Use

According to the directions for use the coverage of paint is about 6-8 m²/l (product information, <http://www.sikkens.nl/nl/Products/ProductsOverview>, 06-10-2006).

Scenario

The scenario describes the brushing or rolling of two walls in a small room with low ventilation. Room size en ventilation rate as described in the General Fact Sheet³⁾ a for an unspecified room (volume 20 m³, ventilation rate 0.6 h⁻¹).

Painted surface, release area

Room: 20 m³ (see scenario); l x w x h = 4 x 2 x 2.5 m

The surface of two walls is (4 + 2) x 2.5 = 15 m²

Product amount

With 1 liter latex 6 m² can be painted. For painting two walls of in total 15 m², 2.5 liter or 3.75 kg paint is necessary (density 1.5 g/cm³ (see composition)).

Default values brush / roller painting, waterborne wall paint

	Default value	Q	Reference, comments
<i>General</i>			
Frequency	2 year ⁻¹	3	estimation based on ^{4,7)}
Body weight	65 kg	4	adult ³⁾

Inhalation

Exposure to vapour: evaporation from increasing area

Exposure duration	132 min	2	see section 2.1.1
Application duration	120 min	2	estimate
Product amount	3750 g	3	see above
Room volume	20 m ³	3	unspecified room ³⁾
Ventilation rate	0.6 h ⁻¹	3	unspecified room ³⁾
Release area	15 m ²	3	see above
Temperature	20 °C	4	room temperature
Mass transfer rate	Thibodeaux		see section 2.1.2
Mol weight matrix	120 g/mol	3	see section 2.1.3

Dermal

Constant rate

Contact rate	30 mg/min	2	see section 2.2
Release duration	120 min	2	see above (release duration is application duration)

2.7 Two-component paints

Two-component paints consist of two separate components, a base lacquer and a hardener. Both components must be mixed together just before painting. The two components react chemically, then hardening can occur.

Composition

In Table 8 examples of the composition of two-component epoxy and polyurethane paints are described, including some frequent used compounds. The examples are derived from Arbouw, 2006¹¹⁾.

Table 8: Examples of the composition of two-component paints

Ingredient	Polyurethane		Epoxy		
	waterborne	solvent based	waterborne	'solvent free'	solvent based
Component A					
binder	40-50 %	30-40 %	50 %	50-60 %	40-50 %
pigments/fillers	20 %	20 %	20 %	20 %	20 %
solvent	2-8 % N.methyl-pyrrolidon, glycols	30-50 % xylene, butanole	water and 5-10 % glycols	5-20% benzyl alcohol	30-40 % xylene, alcohols
reactive diluent	----	----	10-25 %	10-25 %	----
additives	0-5 % wetting agent	0-5% wetting agent	0-5% wetting agent	0-5% wetting agent	0-5% wetting agent
Component B					
hardener	75-100 % poly isocyanate	50-75 % poly isocyanate	50-75 % amine-epoxy adduct	50-75 % polyamine	50-75 % polyamine and/or adduct
solvent	water , ca 5 % glycols	25-50 % xylene	water and 5-10 % glycols	25-50 % benzyl alcohol	50 %5 xylene, butanol

Reactive dilutants are found in waterborne and 'solvent free' epoxy paints. These ingredients have chemical similarities with respect to epoxy resins, however they are less viscous, and they can evaporate. They dilute the epoxy resin. During hardening they form a part of the paint layer. Only a very small fraction of the reactive dilutant really evaporates.

Use

There are two-component paints with polyurethane and with epoxy binders. These two types of paint are used for different applications, as described in Table 8.

Table 9: Two-component paints

Binder	Types of paint	Applications (examples)
Polyurethane	solvent rich high solid waterborne dispersion	top layer on metal and on epoxy floor coating top layer on metal and on epoxy floor coating wooden stairs inside, parquet lacquer
Epoxy	solvent rich high solid waterborne emulsion	metal, corrosion resistant, outside metal, corrosion resistant, outside metal, stony floors and walls, inside and outside

Two-component paints are mostly used by professionals, but consumers use them too. For example two-component epoxy coating on boats and two-component polyurethane parquet lacquer on parquet. Consumers can buy two-component parquet lacquer for instance at the paint special shop and yacht paints at for instance the water sport special shop.

Mixing and loading

The base lacquer and the hardener of a two-component paint have to be mixed immediately before use. For mixing and loading of two-component paint default values are described.

During mixing of the two components inhalation can occur due to evaporation and dermal exposure due to spills and spatters.

Application

For the application of two-component paint products no separate default values are developed. For painting with two-component paints the default values for solvent rich, high solid, or waterborne paints can be used.

Because this type of paints is used for specific purposes, some default values will have to be changed to cover that specific purpose. For example for painting the floor with a two-component waterborne dispersion lacquer, the default values for waterborne paint can be applied (see section 2.5). The standard scenario for waterborne paint describes the painting of a lathed wall. Where this paint is used to paint the floor, some parameter values have to be adjusted; the release area (the surface of the floor), the used product amount of paint and the exposure and application duration.

Scenario

If two-component paints are used by consumers, they use them for specific purposes (see use). Therefore, a general scenario for the use of two-component paints is not described.

2.7.1 Mixing and loading: two-component paints

The mixing of the two components, the base lacquer and the hardener, immediately before painting may lead to inhalatory and dermal exposure. The two components are put together according to the ratio, which is provided by the manufacturer. The base lacquer and the hardener are then mixed with a spatula until a homogeneous colour is obtained.

When mixed the two components react chemically and hardening can occur.

After mixing, the mixed paint can be used during a specific time: the 'pot life'.

Inhalation exposure can occur if volatile compounds evaporate during the mixing process. It is unlikely that the volatile compounds will be formed during the chemical reaction between base lacquer and hardener, because polymers are formed to provide the bond.

Inhalation exposure

As default model to describe the inhalation exposure from mixing and loading the 'exposure to vapour: evaporation model' is selected.

Frequency

Painting with two-component paints is a specific task, which does not occur with high frequency. Therefore a default of once per three years is assumed.

Exposure duration, release area

The duration of the mixing and loading process is estimated to be five minutes. Evaporation occurs from a constant surface area, i.e. the surface of the paint can in which the components are mixed together. The surface area is estimated at 95 cm².

Room volume and ventilation rate

'Room volume' is interpreted here as 'personal space': a small volume of 1 m³ around the user. A small volume around the user is relevant for the inhalation exposure of the user, for the short use duration in which the treatment takes place. The ventilation rate for an unspecified room (i.e. 0.6 hr⁻¹) is used, because no information is available on the ventilation rate near the user.

Product amount

The product amount, the quantity of paint which is mixed and loaded, depends on the scenario which is chosen for the application of the two-component paint.

As described before a scenario is not given here.

Dermal exposure

To describe dermal exposure the instant application model is selected. This model describes exposure assuming that all substance in the product is directly applied to the skin.

Dermal exposure could occur due to spills around the opening of the paint can and spatters during mixing both components. Information about dermal exposure of paint products during the mixing and loading process was not found.

For mixing and loading of pesticides by consumers PSD¹⁹⁾ provides information.

The contamination from emptying different volume containers with wide necks, loaded with liquids, varies from 0.01 to 0.05 ml per operation, depending on the container size.

Dermal exposure of non-professionals due to dispensing and diluting concentrated biocides from a one-litre can with water in a bucket, is described in the Technical Notes for Guidance, Human Exposure to Biocidal Products¹⁾. The dermal exposure of hands and forearms results in a range from 0 to 3.2 mg/event (averaged over four events) and in a worst case single event of 12.8 mg/event.

Based on the information above the default value for the quantity of product that ends up to the skin is set at 50 mg/event (value derived from the PSD; 0.05 ml per operation = 50 mg, if the density of the liquid is 1 g/cm³).

Default mixing and loading: two-component paint

	Default value	Q	Reference, comments
<i>General</i>			
Frequency	1/3 year ⁻¹	1	See above
Body weight	65 kg	4	adult ³⁾

Inhalation**Exposure to vapour: evaporation constant
release area**

Exposure duration	5 min	2	See above
Application duration	5 min	2	See above
Product amount			No value, see above
Room volume	1 m ³	1	See above
Ventilation rate	0.6 h ⁻¹	1	See above
Release area	95 cm ²	2	See above
Temperature	20 °C	4	Room temperature
Mass transfer rate	Langmuir		See section 2.1.2
Mol weight matrix	3000 g/mol	3	See section 2.1.3

Dermal**Instant application**

Product amount	50 mg /event	1	See above
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2.8 Miscellaneous, special paint products

There are many special paint products for specific purposes, e.g. chlorinated rubber paints and adhesive primers. Chlorinated rubber paints can be used for painting boats (product information, http://www.sikkensyachtpaint.com/pdf/download/nl_guide_2005.pdf, 6-10-2006). Adhesive primers can be used to paint plastics. They can contain other solvents compared to the more general types of paint in order to soak the synthetic material.

Use

These special paint products used for specific purposes are mainly used by professionals, but also by consumers. Chlorinated rubber paints are for example sold in water sports specialist shops.

Default values for special paint products

For special paint products no separate default values have been proposed. Default values for solvent rich, high solid, or waterborne paints can be used for this product category as well. Because these types of paint are used for special purposes, usually some default values have to be adjusted to describe that specific scenario. For example painting the synthetic doors of a kitchen with an adhesive primer, the room will be the kitchen (default value see General Fact Sheet³⁾) and the release area the surface area of the painted kitchen doors. The product amount of the used paint has to be adjusted to the painted surface.

3 Spray Painting

Consumers can spray paint products with aerosol spray cans and, to a lesser degree, also using a compressor. When using a compressor, paint products are sprayed almost always pneumatically. During pneumatic spraying the working pressure is about 2-6 bar, and the air consumption rate circa 130-250 l/min (product information; <http://www.ferm.nl/nl>, dd 03-01-2007;

<http://www.sikkens.nl/nl/Products/ProductsOverview/Rubbol+BL+Easy+Spray+Gloss.htm?ser=937070365>, dd 11-12-2006), user information via the internet (<http://www.brommerforum.nl/topics/5>, dd 20-10-2006).

On the internet one company was found, which offered spray guns for airless spraying for consumer use

(http://www.onlinebouwmarkt.nl/winkel/view_product.php?product=VERW8QWE1&searchlink=yes&search=VERFSPUIT&page=1, dd 20-10-2006). During airless spraying the spraying pressure is much higher, circa 130 bar. It is assumed that airless spraying by consumers will hardly occur.

Airless spraying is a spray painting process that uses hydraulic pressure instead of air to atomize the paint. Atomization is achieved by forcing the paint at high pressure (ca 125-200 atm) through a spray nozzle with a small orifice. The spray pattern and flow of paint are controlled by the size and shape of the orifice. One of the main advantages of airless spraying is that the paint materials do not need to be thinned as much as in air spraying, thereby producing higher film build and better hiding

There is one pump sprayer on the market, which can be used to spray garden stain on wood in the garden, for example on fences. The working pressure is 4 bar

(http://www.cuprinol.nl/cuprinol_sprayer_assortiment.php, dd 20-10-2006).

In this chapter spraying with aerosol spray cans and pneumatic spraying using a compressor, are described. No examples were found of airless spraying by consumers; therefore, no default scenario for this type of spraying is described. The inhalation exposure to aerosol particles formed during spraying is described by the spray model from ConsExpo. In section 3.1 general information about the spraying process, paint spraying and general parameter values for the spraying process are described. In section 3.2 and 3.3 default models with default parameter values are stated for spraying with a spray can and for pneumatic spraying.

Spraying garden stain with a pump sprayer should be described with the same model, which describes pneumatic spraying, if spraying occurs indoors. The working pressure is comparable, and it is assumed that the initial particle distribution is also comparable.

The ConsExpo models, which describe the inhalation exposure, are developed for indoor application. The spray model from ConsExpo does not describe outdoor application.

In the 'Technical Notes for Guidance, Human Exposure to Biocidal Products'¹⁾ spraying outdoors by consumers is only described for spraying of fences with an electric powered sprayer (consumer product spraying and dusting, model 3), not for other spraying devices. Other models, which describe surface spraying *outdoors* by consumers are lacking.

Surface spraying *indoors* by consumers can be described with ConsExpo and with consumer product spraying and dusting model 2 and model 3 from the TNsG¹⁾. It is assumed that the inhalation exposure indoors will be higher than outdoors for an identical application.

Describing an outdoor application with these models, which are meant for indoor application,

results in a too high value for the exposure. However, this might serve as a worst case estimate.

3.1 General parameters for the spraying process

During spraying, an aerosol cloud of very small to small droplets is formed. The user can inhale these aerosol particles.

To calculate the inhalation exposure to aerosol particles, the 'spray model' from ConsExpo is used for both spraying with a spray can and spraying using a compressor. In section 3.1.1 some parameters from the 'spray model' are discussed, which are used for both spraying applications.

To calculate the dermal exposure of the user during application the 'constant rate' model from ConsExpo is used for both spray applications.

In the previous version of this report other default models were proposed to describe the spraying process. The 'spray model' from ConsExpo is developed after the previous version of this report was written.

3.1.1 Parameters for the spray model

The ConsExpo spray model is developed on the basis of the results of experimental work and describes the indoor inhalation exposure to slightly evaporating or non-volatile compounds in droplets that are released from a spray can or pump spray (Delmaar et al.)^{2, 12)}. For volatile compounds, the evaporation model is more appropriate. If the spray model is used for volatile compounds, inhalation exposure will be underestimated, because exposure to vapour is not considered in the spray model.

'Volatile' is defined as compounds with vapour pressure > 0.1 Pa, 'non-volatile' < 0.01 Pa and 'slightly volatile' between 0.01 and 0.1 Pa¹³⁾.

- *Initial particle distribution*

The droplet size is an important parameter when estimating exposure via inhalation. Smaller drops fall at a lower speed and stay in the air for longer. The large droplets will quickly disappear from the air after being formed. As an indication: the falling time of droplets with a diameter of 100 µm from a height of 3 metres is calculated at 11 sec, and for droplets of 10 µm it is calculated at 17 min¹⁴⁾. If a larger droplet is sprayed, part of the aerosol cloud will consist of finer droplets, which stay in the air longer, as a result of edge effects around the nozzle and the 'bounce back' effect due to spraying onto a surface. A WHO classification concerning the droplet size of sprays is provided in Table 10, according to data from the Biocides Steering Group¹⁴⁾.

Table 10: Classification of aerosol droplets¹⁴⁾

Droplet diameter [µm] ^{a)}	Classification
< 15	Fog
< 25	Aerosol, fine
25-50	Aerosol, coarse
51-100	Mist
101-200	Spray, fine
210-400	Spray, medium
>400	Spray, coarse

^{a)} The median diameter; half of the particles are larger, half are smaller

The Dutch Aerosol Association¹⁵⁾ distinguishes between aerosol sprays in aerosol cans with very fine atomized dry sprays (such as asthma sprays and insecticides) and fine atomized wet sprays (such as hair sprays and paint sprays).

Matoba et al.¹⁶⁾ measured the droplet size of an aerosol can with a spray for air space applications. The average droplet size was 30 µm with a range of 1-120 µm. Based on the measurements, Matoba et al. classified the droplets into three groups: 10 % of the particles have a droplet size of 60 µm, 80 % have a droplet size of 20 µm and 10 % of the particles have a droplet size of 5 µm. A spray for air space applications generally has a smaller droplet diameter than a spray for surface applications.

TNO-PML¹⁷⁾ has investigated the initial particle size distributions from aerosols spray cans and trigger sprays. The investigated spraying devices were aerosol spray cans, ready-to-use trigger sprays and plant sprayers with an adjustable nozzle to produce a spray with droplets as small as possible or a spray with coarse droplets.

In this investigation, the initial particle size distribution of two spray paints was measured. The percentiles of these sprays are given in Table 11. The 10, 50, and 90 percentiles for the volume distributions of the spray cans are given as $d_p(V, 0.10)$, $d_p(V, 0.50)$ and $d_p(V, 0.90)$, which means that 10%, 50% or 90% of the product mass is below the mentioned size.

Table 11: Percentiles of the initial volume distribution of aerosol spray cans with paint¹⁷⁾

Application	Content	Percentiles of the initial particle distribution [µm]		
		D _p (0.10)	D _p (0.50)	D _p (0.90)
Surface spraying, aerosol cans				
Paint 1	Full	27	114	352
	Nearly empty	20	76	186
Paint 2	Full	11	39	88
	Nearly empty	10	37	101

In paint 1, water is one of the solvents. Paint 2 is a solvent based paint.

More information about particle size distributions of aerosol spray cans with paint was not found.

- *Aerosol spray cans*

The default initial particle distribution is based on above-mentioned data generated by TNO-PML. Default: lognormal distribution with median 30 µm, coefficient of variation 0.8. (see Figure 1)

- *Pneumatic paint spraying and pump spraying by consumers*

No information was found about initial particle size distribution of non-professional pneumatic spraying of paint, nor about spraying stain using a pump sprayer. The investigated spraying devices by TNO-PML¹⁷⁾ were aerosol spray cans, ready-to-use trigger sprays and plant sprayers with an adjustable nozzle to produce a spray with droplets as small as possible or a spray with coarse droplets. For trigger sprays and plant sprays all measured initial particle distributions had median values higher than 50 µm¹⁹⁾. Until more information is available the default value for the initial particle distribution of spraying paint pneumatically or using a pump sprayer is set at a lognormal distribution with median 50 µm, coefficient of variation 0.6, (see Figure 2), which is the

default value for the initial particle distribution for trigger sprays.
The default values for the initial particle distributions are given in Table 12.

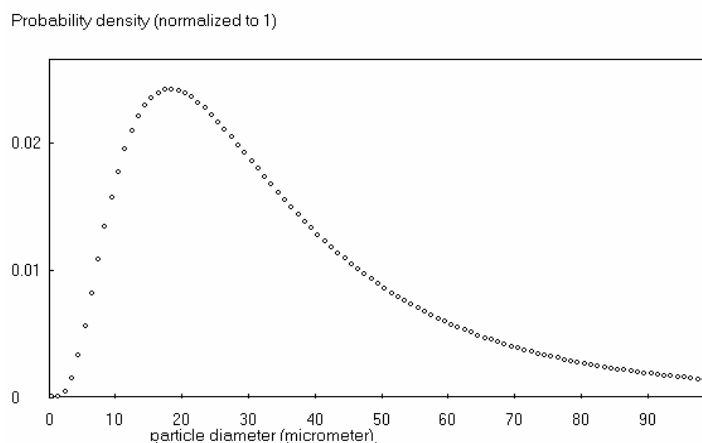


Figure 1: Default initial particle distribution for paint spray cans i.e. a lognormal distribution with median 30 μm (C.V. 0.8)

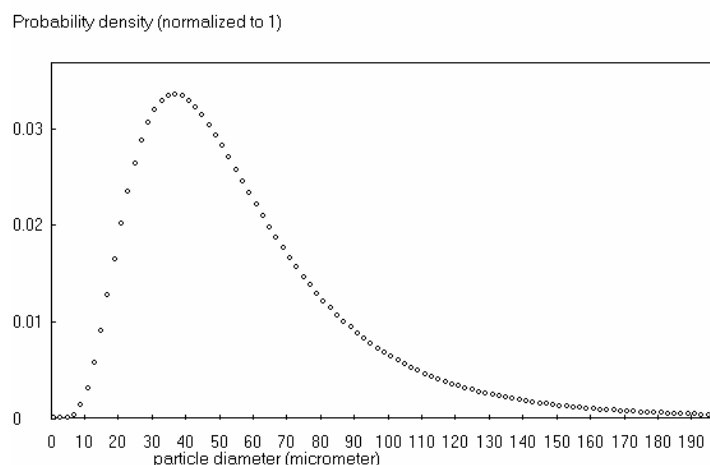


Figure 2: Default initial particle distribution for spraying paints using a pneumatic sprayer or a pump sprayer i.e. a lognormal distribution with median 50 μm (C.V. 0.6)

Table 12: Default values initial particle distribution spraying paint

Paint spraying	Distribution	Median [μm]	C.V. ^{a)}	Q
Aerosol spray can	Lognormal	30	0.8	2
Pneumatic sprayer, pump sprayer	Lognormal	50	0.6	1

^{a)} C.V.: Coefficient of Variation

- *Airborne fraction*

The airborne fraction is the fraction of non-volatile material that becomes airborne in the form of droplets. The ‘airborne fraction’ combines the non-volatile material fraction that ends up in the smaller droplets and the fraction of droplets that becomes airborne. The latter is

closely connected to the type of spray and the way it is used, for example spraying on a surface (paint, wood preservative) or spraying in the air (spraying against flies), and on the droplet size distribution that has been specified.

Airborne fractions have been determined experimentally for different sprays. The airborne fraction is derived from the TNO-PML¹⁷⁾ survey on the exposure from spray cans and trigger sprays (Delmaar et al., in prep.)¹²⁾. The airborne fractions for the investigated spray cans and trigger sprays are presented in Table 13. Based on these values, default values are set (see Table 14).

Table 13: Airborne fractions of investigated spray cans and trigger sprays

Application	Percentiles of the initial particle distribution [µm]			Main solvents	Airborne fraction [%]
	D _p (0.10)	D _p (0.50)	D _p (0.90)		
Spray cans					
Air space, against flies and mosquitoes	25	125	414	water	60
Air space, against flies	7	23	109	isoparafine/ isopropanol	60
deodorant	7.6	22	41	ethanol	100
Hair spray	17	39	69	dimethyl ether / ethanol	100
Flea spray	9.4	30	142	benzine/ acetone	50
Plant spray Affecting insects	55	97	232	water	10
Trigger sprays					
Plant spray fine ^a , affecting insects	33	88	191	water	20
Plant spray coarse ^a , affecting insects	39	127	512	water	20
Spray against crawling insects	29	63	200	water	10
All purpose cleaner	46	133	391	water	10

- a) The nozzle can be adjusted so that the plant sprayer generates a fine spray with droplets as small as possible or a spray with coarse droplets

Table 14: General default values for the airborne fraction

	Airborne fraction	Q
Air space sprays	1	2
Surface sprays; median of the initial particle distribution < 50 µm	1	2
Surface sprays; median of the initial particle distribution ≥ 50 µm	0.2	2

Based on these general default values the airborne fraction the default value for paint spray cans is set at 1 and for paints sprayed pneumatically or with a pump sprayer at 0.2.

- *Inhalation cut-off diameter*

The inhalation cut-off diameter is the measure for the diameter of the spray droplets that can be inhaled and reach the lower areas of the lungs (alveoli, bronchioles, bronchia). Particles larger than this diameter deposit in the higher parts of the respiratory tract and will be cleared via the gastro-intestinal tract, leading to oral exposure. The inhalation cut-off diameter is only an approximation of the complicated process of deposition of particles in the lung. In general, this value will be around 10-15 μm . The default value is set at 15 μm .

- *Density*

In the spray model, the density of the non-volatile fraction is one of the parameters. Many non-volatile substances in paint products are composed of large organic compounds with densities usually between 1.0 and 1.5 g/cm^3 . For a complex mixture of (especially organic) compounds, the density is set at 1.8 g/cm^3 . The density of salts generally varies between 1.5 and 3.0 g/cm^3 . In Table 15 default values are described for solvents and for non-volatile compounds.

Table 15: Default values for density

Type	Main ingredient	Density [g/cm^3]	Q
Solvents	Volatile organic solvents	0.7	3
	Water	1	4
Non-volatile compounds	Large organic compounds	1.5	3
	Salts	3.0	3
	Complex mixture of compounds, especially organic compounds	1.8	3

3.1.2 Parameters for the ‘constant rate’ model

To calculate dermal exposure of the user during application the ‘constant rate’ model from ConsExpo is used for both spray applications, i.e. spray cans and pneumatic spraying. Exposure measurements of surface spraying with pre-pressurized aerosol spray cans and hand-held trigger sprays spraying by consumers are described in the TNsG¹⁾. The measured data for dermal exposure have a wide range. The default values for the contact rate (the main parameter in the ‘constant rate’ model) are derived from these measurements.

- *Contact rate aerosol spray cans*

In the TNsG¹⁾, in ‘Consumer product spraying and dusting’, a surface spraying model is stated in which the consumer uses an pre-pressurized aerosol spray can for spraying surfaces, i.e. a skirting board, dining chairs, a sofa and carpet. The dermal exposure on hands and forearms ranges from 1.7 to 156 mg/min with a 75th percentile of 64.7 mg/min . The dermal contact rate for legs, feet and face ranges from 17 to 45.2 mg/min with a 75th percentile of 35.7 mg/min .

Using these data, the default value for contact rate during spraying with a spray can, for the total dermal exposure, is set at 100 mg/min .

- *Contact rate pneumatic spraying*

In the TNsG's¹⁾ 'Consumer product spraying and dusting' a surface spraying model is stated in which the consumer uses a hand-held trigger spray for spraying surfaces i.e. skirting boards, shelves and horizontal and vertical laminate with a wood preservative. The dermal exposure on hands and forearms ranges from 3 to 68.2 mg/min with a 75th percentile of 36.1 mg/min. The dermal contact rate for legs, feet and face ranges from 1.9 to 12.4 mg/min with a 75th percentile of 9.7 mg/min. Using these data, the default value for contact rate for hand-held trigger sprays in the Pest Control Product Fact Sheet¹⁸⁾ was set at 46 mg/min. In the TNsG's¹⁾ 'Consumer product spraying and dusting' a surface spraying model is stated in which the consumer uses an electric powered sprayer outdoors for all types of fence with a wood preservative.

The dermal exposure on hands and forearms ranges from 32.4 to 144 mg/min with a 75th percentile of 72.6 mg/min. The dermal contact rate for legs, feet and face ranges from 13.4 to 84 mg/min with a 75th percentile of 39.9 mg/min.

Based on the data above the default value for the contact rate during pneumatic spraying, for the total dermal exposure, is set at 110 mg / min.

Table 16: Default values contact rate for spray cans and pneumatic sprayers

	Contact rate [mg/min]	Q
Spray can		
surface spraying	100	3
Pneumatic sprayer		
surface spraying	110	2

3.2 Spraying paint with a spray can

Composition

Propellants used in paint spray cans usually are di-methyl ether or a mixture of propane and butane. If propane/butane is propellant in paint spray cans, often white spirit/acetone is the solvent (product information; ^{20; 21)}).

The Dutch sector association for paint and printing ink manufacturers (VVF^{a)}) indicates that ether is by far the most used propellant in paint spray cans. If ether is propellant, it functions as solvent too. As binder, in solvent soluble acrylates are used. Therefore the product in the spray can is not a dispersion.

The Netherlands Organisation for Applied Scientific Research (TNO^{b)}) declares that the binder usually is an alkyd resin, and that, to a much lesser extent, cellulose lacquers are used.

In paint spray cans the solid compounds are dissolved in the solvent. Most other paints are dispersions; the solid compounds are colloid particles in the liquid. Paint products which are sprayed pneumatically, usually are dispersions.

a) Personal communications VVF, dd 24-10-1997; 12-11-1998

b) Personal communications TNO-Industrie, dd 22-12-1997; 12-11-1998

Based on the composition of paint spray cans the weight fraction of the non-volatile part of the components in the spray can is assessed at 0.3. The default value for the density of the non-volatile part of the components is set at 1.5 g/cm^3 , based on the composition of the product and the densities as described in Table 15.

Use

Paint spray cans are for example used for painting of radiators, bikes and auto repair. In Weegels⁴⁾ one person using spray paint is described. The distance from the nozzle to the nose varied between 20 and 50 centimeters.

Scenario

As default scenario for spray paint with a spray can, spraying of a whole spray can of 400 ml, to paint a radiator in a garage is selected. It is assumed that the garage is left 5 minutes after spraying.

Inhalation and dermal exposure of spray particles is described below. To describe the inhalation exposure, the spray model is used, and to describe the dermal exposure, the constant rate model.

Inhalation exposure of propellants and solvents is not described. In 'ConsExpo 4 Spray Model. Description and Experimental Validation'¹²⁾ it is assumed that propellants and solvents evaporate instantaneously during spraying. To calculate the inhalation exposure of these components the instantaneous release mode of the evaporation model can be used.

Inhalation exposure

Product amount

In the scenario it is stated that a paint spray can of 400 ml is sprayed. Based on the composition of the product and the densities, as described in Table 15, it is assumed that the density of the product in the spray can is 0.75 g/cm^3 , therefore the product amount in the spray can is 300 g.

Application duration / release area

In Weegels⁴⁾ one case of paint spraying with a spray can is described. In total 29 g of paint was sprayed, the time during which the spraying took place was 5 minutes.

Product information of Akzo Nobel²¹⁾ indicates that $1.5\text{-}2 \text{ m}^2$ can be sprayed with a spray can of 400 ml. The distance from the spray can to the object ought to be 15-30 cm; 5 minutes after spraying the paint is dust-dry, and can be resprayed. After 15 minutes, the paint is dry (propellant/solvent: ether).

The Dutch sector association for paint and printing ink manufacturers (VVVF^{a)}) indicates that spraying a surface of $1.5\text{-}2 \text{ m}^2$ with a spray can of 400 ml can be seen as maximal value, in practice the sprayed surface usually will be smaller. The time span of emptying a 400 ml spray can is estimated at 10 to 15 minutes^{a)}.

Based on these data the default value for the application duration (the time span which is sprayed) is set at 15 minutes. For the release area (the painted surface) 2 m^2 is assumed.

Mass generation rate

As described above, 300 g of paint is sprayed in 15 minutes. The *mean* mass generation rate is calculated to be 0.33 g/sec .

a) Personal communications VVVF, dd 24-10-1997; 12-11-1998

In the TNO report ‘Aerosols from spray cans and trigger sprays’¹⁷⁾ the mass generation rate during *actual* spraying of the two investigated spray cans is described: 0.6 g/sec. This indicates that in the time span during which spraying take place (= spray duration) about half of this time actually is sprayed.

Default for spraying paint with a spray can

	Default value	Q	Reference, comments
General			
Frequency	2 year ⁻¹	2	estimation
Body weight	65 kg	4	adult ³⁾
Inhalation			
<i>Exposure, spray model</i>			
Spray duration	15 min	2	See above
Exposure duration	20 min	2	See scenario
Room volume	34 m ³	3	Garage ^[3]
Room height	2.25 m	3	Garage ^[3]
Ventilation rate	1.5 h ⁻¹	3	Garage ^[3]
Mass generation rate	0.33 g/sec	3	See above
Airborne fraction	1 g/g	2	See section 3.1.1
Weight fraction non-volatile	0.3	1	See composition
Density non-volatile	1.5 g/cm ³	2	See composition
Initial droplet distribution – median (C.V.)	30 µm (0.8)	2	See section 3.1.1
Inhalation cut-off diameter	15 µm	3	See section 3.1.1
Dermal			
<i>Constant rate</i>			
Contact rate	100 mg/min	3	See section 3.1.2
Release duration	15 min	2	See above

3.3 Pneumatic spraying

Composition

The paint which is sprayed during pneumatic spraying is the same as the paint which is applied by means of brushing or rolling. The only difference is that paints which are sprayed have to have a specific viscosity. Solvents can be added to make a product which can be sprayed properly. The solvents are the same as used by brushing / rolling (usually white spirit).

The general composition of the sprayed paint equals the composition of a conventional solvent rich paint⁶⁾.

Binder	± 35 %	for example alkyd resin
Pigment	25 %	for example titanium dioxide
Solvent	40-50 %	for example white spirit
Additives	± 2 %	dryer 1 %; anti-skin product 0.2-0.5 %; anti-sag product 0.5 %; moistener 0.5 %

Use

The distance between the spray gun and the surface to spray ought to be 30 cm²²). The working pressure is about 2-6 bar, and the air consumption circa 130-250 l/min (product information; <http://www.ferm.nl/nl/>, dd 03-01-2007).

Scenario

As default scenario for pneumatic spraying, painting of two radiators in a garage is selected. It is assumed that the *mean* mass generation rate is 50 % higher than for a spray can, i.e. 0.5 g/sec.

Inhalation exposure*Product amount / release area*

The painted surface (= release area) is set at 4 m², twice as much as for one radiator, as described before for spraying with a spray can.

If it is assumed that the quantity of paint, expressed as non-volatile substance per m² painted surface, is the same as for spraying with a spray can (spraying with a spray can: 300 g for 2 m², 30 % non volatile substances), then the product amount to paint 4 m² with a pneumatic sprayer (paint 50 % non volatile) is calculated at 360 g paint.

For brushing/rolling with a solvent rich paint (see section 2.3) 100 g of paint is necessary per m². The default value for the product amount to spray 4 m² radiators is set at 400 g paint.

Spray duration / exposure duration

Spraying 400 g of paint with a mean mass generation rate of 0.5 g/sec (see scenario) lasts 800 sec (13.3 minutes). It is assumed that cleaning after spraying lasts circa 10 minutes and that the garage is left afterwards. Therefore the exposure duration is 25 minutes

Default for pneumatic spraying of paint

	Default value	Q	Reference, comments
<i>General</i>			
Frequency	2 year ⁻¹	2	estimation
Body weight	65 kg	4	adult ³⁾
Inhalation			
<i>Exposure, spray model</i>			
Spray duration	800 sec	1	13.3 minutes, see above
Exposure duration	25 min	1	See above
Room volume	34 m ³	3	Garage ^[3]
Room height	2.25 m	3	Garage ^[3]
Ventilation rate	1.5 h ⁻¹	3	Garage ^[3]
Mass generation rate	0.5 g/sec	1	See scenario
Airborne fraction	0.2 g/g	2	See section 3.1.1
Weight fraction non-volatile	0.5	2	See composition
Density non-volatile	1.5 g/cm ³	3	See section 3.1.1
Initial droplet distribution – median (C.V.)	50 µm (0.6)	1	See section 3.1.1
Inhalation cut-off diameter	15 µm	3	See section 3.1.1
Dermal			
<i>Constant rate</i>			
Contact rate	110 mg/min	2	See section 3.1.2
Release duration	800 sec	2	See above

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